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northwest hydraulic consultants

NHC Ref. No. 03000276

21 November 2014

Wedler Engineering LLP
#211-2459 Cousins Avenue
Courtenay, BC
V9N 3N6

Attention: Andrew Gower, P.Eng.

Via email: agower@wedler.com

Re: **Lazo Road Shoreline Protection**
Wave Climate Assessment

Dear Mr. Gower:

Northwest Hydraulic Consultants (NHC) is pleased to submit this assessment of the wave climate at Lazo Road, Comox.

1 SCOPE OF WORK

As set out in our letter of October 9, 2014 the scope of work includes the following tasks:

1) Conducting a site visit and meeting to review the project plans and technical issues. A site inspection was carried out by D. McLean on October 14, along with Andrew Gower of Wedler Engineering, Darryl Furey of Levelton Consultants and Warren Fleenor of Current Environmental.

2) Compiling and analysing long-term wind data from nearby weather stations (Comox Airport and offshore wave stations) to develop frequency distributions of extreme winds.

3) Reviewing and analyzing wave observations in the Strait of Georgia to estimate the frequency and magnitude of waves (characterized by the significant wave height and wave period).

4) Reviewing extreme tides and storm surge levels and estimating appropriate design water levels at the site.

5) Determining appropriate combinations of winter waves and high tide levels to provide design conditions for shoreline protection measures.

Design of the shoreline protection measures at Lazo Road will be carried out by others. NHC will provide comments on the measures that are proposed at a later date.

2 AVAILABLE INFORMATION

The proposed project is described in the report "Lazo Road Shoreline Protection and Restoration, Preliminary Design Report", by Wedler Engineering Ltd. dated November 15, 2011. Appendix A, Levelton Consultants Geotechnical Review, included a review of the erosion processes and provided a conceptual riprap design of a revetment to protect the shoreline.

Updated topographic surveys of the shoreline were conducted by Wedler Engineering in October 2014. The survey information was supplied to NHC on October 31 in AutoCAD format (file V15-0196A Lazo Bank.dwg). The surveys covered the 700 m length of the project and were referenced to geodetic datum (CGD).

3 SITE CONDITIONS

3.1 Project Extent

The proposed protection extends over a distance of 700 m (Wedler, 2011). In this section the road is set-back between 4 to 10 m from the edge of the backshore and is presently unprotected. The road elevation varies typically between 5.0 m and 5.5 m and reaches its lowest level of 4.0 m CGD at the roads northeast end of the project.

3.2 Beach Characteristics

A site inspection was made on the morning of October 14th, when the tide level ranged between elevation 1.0 and 1.3 m CGD. By comparison, Higher High Water Mean Tide (HHWMT) is elevation 1.5 m CGD. Photos of the beach are attached at the end of this report. The approximate elevations of shoreline features on these photos were estimated from the 0.25 m contour map provided by Wedler.

The beach is exposed to waves approaching from the southeast. Figure 2 and Table 2 summarize the bio-morphological characteristics of the beach and foreshore. This information was prepared by Warren Fleenor of Current Environmental (Current). Current indicated this information is preliminary.

This section of the coast consists of two main morphological features:

- Foreshore, which extends from Lower Low Water (LLW) to Higher High Water (HHW) and consists of a gravel and cobble beach having a width of typically 50 m. The upper portion of the beach has a slope of 1V:20H and is frequently covered by logs and large woody debris (LWD). Portions of the lower beach berm include midden-type materials (mainly sandy gravel and shell fragments) and are being actively undercut by wave erosion (Photo 2).

- Backshore, which extends up to 4 m above HHW (to elevation 6 m CGD) and consists mainly of sandy dune deposits and berms, covered by grasses and shrubs. The backshore dunes materials that are easily erodible and are subject to gullying from wave run-up, spray, runoff and foot traffic.

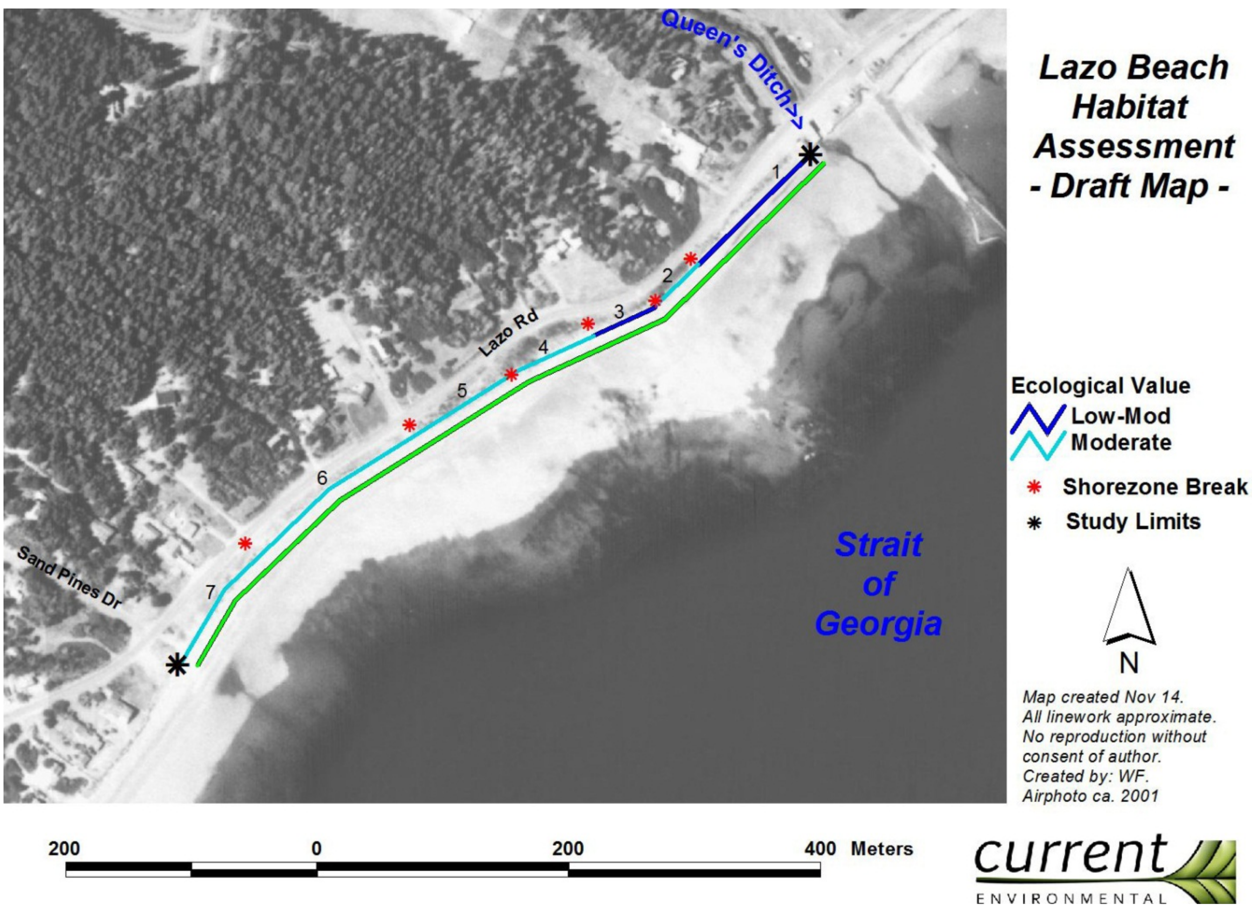

Figure 1: Site plan

Table 1: Preliminary summary table for Lazo Beach survey

Shorezone	Forage Fish	LWD	Erosion	Riparian Vegetation	Ecological Value	Comments
1	Low-Mod	Mod	Low-Mod	Poor	Low-Mod	- Tight proximity to road. - Consider expanding riparian area into shoulder/parking area. - Small area of riprap. - Queen's Ditch estuary/freshwater input at northern extent of shorezone.
2	Low-Mod	Low-Mod	None	Mod	Moderate	- Thicket with abundance of native vegetation. - Small tidally inundated depression behind berm (dune slack?). - Good but small area of wildlife habitat. - Marginal beach pea/dunegrass community that is rare.
3	Low-Mod	Low	None	Poor	Low-Mod	- Non-native grass dune form. - Shore is stable.
4	Mod	Low-Mod	None	Mod	Moderate	- Patchy thicket with well developed berm (poorly embedded LWD). - tidally inundated depression (slack). - Potential model for riparian habitat design?
5	Low-Mod	Low-Mod	Low	Poor	Moderate	- Remnant dune form/wide backshore. - Well developed bench with beach pea/dunegrass and LWD (not embedded). - Some fill placed during road construction? - Backshore is non-native grass dominated community. - Appears stable. - Coarse cobble band in berm helping dissipate energy? - Model for slope design?
6	High	Mod	High	Poor	Moderate	- Good quality forage fish spawning habitat a result of erosion? (Photo 6-B). - Power poles exposed. - Abundance of public access issues. - Restore beach pea/dunegrass community. - Narrow backshore and riparian a result of proximity to road. - Wide berm/beach area to work with.
7	High	High	High	Low	Moderate	- Weedy grass community on wider backshore/dune form. - Good quality forage fish spawning habitat a result of erosion? - Wide beach to work with. - Well-functioning berm with embedded LWD and dunegrass zone (Photo 7-E). - Significant erosion/rilling from road runoff noted in several areas (Photo 7-B. - Public access also causing significant erosion (including vehicle tracks; Photo 7-C,D). - High potential for restoration?

General Comments

- Entire shore provides important forage fish spawning habitat. Emphasis on softer approach to maintain finer substrates should occur if feasible.
- Road runoff and public access contributing to shore erosion - particularly at SW end.
- In riprap areas, encourage development of berm (transition between beach to riprap slope) through use of embedded LWD and placement of fill?
- Opportunities to enhance riparian vegetation through planting native vegetation in backshore - including riprap area.
- Some areas where expanding backshore into parking areas may be feasible.
- No At-risk species or communities on site due to high disturbance regime, proximity of road.
- Confirmed forage fish spawning in area increases ecological value of study area despite high disturbance history. Confirmatory forage fish survey results will be integrated into future drafts.

4 OCEAN LEVELS AND WAVE CLIMATE

4.1 Tides

4.1.1 Present Conditions

The tides in the Strait of Georgia are characterized as "mixed, mainly semi-diurnal". Fisheries and Oceans Canada (DFO) predicts tide levels at Comox. The published tide statistics for this site are summarized in Table 2. Tide levels are commonly referenced to local Chart Datum (CD), which corresponds to approximately Lower Low Water, Large Tide. These levels were adjusted to Canadian Geodetic Datum (CGD) which corresponds approximately to mean water level.

Table 2: Summary of tide levels

Tide Condition	Abbreviation	Ocean Level	
		Chart Datum (CD m)	Geodetic Datum[1] (CGD m)
Higher High Water Large Tide	HHWLT	5.4	2.1
Higher High Water Mean Tide	HHWMT	4.8	1.5
Mean Water Level	MSL	3.3	0.0
Lower Low Water Mean Tide	LLWMT	1.2	-2.1
Lower Low Water Large Tide	LLWLT	0.0	-3.3

HHWLT is the highest astronomical tide that occurs approximately once per year on average. HHWMT is the average of all daily high waters that occur in a year. The tidal range is approximately 5.4 m.

4.1.2 Sea Level Rise

Sea level has risen over the last century and is projected to continue to rise in the future in response to global climate change. The magnitude of the change is subject to considerable uncertainty. In 2011, the BC Ministry of Environment published guidelines for coastal flood dikes and land use accounting for sea level rise[2]. It was recommended that a sea level rise of 1.0 m for the year 2100 be adopted into planning guidelines. For the case of protecting a road a shorter time frame may be considered. Therefore, we have adopted +0.3 m sea level rise over the next 30 years (i.e. to the year 2045).

4.2 Storm Surge and Set-up

The astronomical tide levels do not include effects caused by storm surges (SS) and wave setup (SU). Storm surges occur over large areas of the Strait of Georgia in response to intense low pressure zones

[1] All elevations in this report are referenced to Canadian Geodetic Datum (CGD) unless otherwise noted.

[2] BC Ministry of Environment 2011: Climate Change Adaptation Guidelines for Sea Dikes and Coastal Flood Hazard Land Use. Report by Ausenco Sandwell, Project No. 143111, 27 January 2011.

that pass across Vancouver Island during storms. The ocean level response due to the differential atmospheric pressure has been recorded at long-term tidal gauges such as Point Atkinson and Campbell River. Storm surges in the Strait of Georgia have reached up to 1 m.

Wave set-up increases the still water level landward of the breaker zone due to the transfer of the wave's momentum to the water column near the shore. Estimates of maximum wave set-up near Cape Lazo from southeasterly storms range from 0.6 to 0.8 m.

The chance of an extreme storm surge and maximum wave set up coinciding with a very high astronomical tide is small. Therefore the adopted reference still water level (SWL) for design of the shoreline protection was determined as follows:

- SWL = HHWMT + SS + SU = 1.5 + 0.5 + 0.8 = 2.8 m CGD (Present).
- SWL = HHWMT + SS + SU + SLR_{30} = 1.5 + 0.5 + 0.8 + 0.3 = 3.1 m CGD (2045 scenario).

The estimate for the level in 2045 accounts only for projected sea level rise, not the effects of increased storm intensity.

4.3 Wave Hindcasting

4.3.1 General

The project site is located north of Balmoral Beach and south of Cape Lazo and is exposed to waves approaching from the southeast and east. The maximum fetch length from the southeast is approximately 90 km. Wind-generated waves are highly irregular and are usually described using statistical methods. For design of coastal protection structures it is common to characterize waves in terms of their significant wave height (H_s) and peak period (T_p). Wind-generated waves are governed by the wind speed during the storm, the fetch length (distance the winds blow over the ocean) and the duration of the storm. Hindcasting methods have been developed by the US Army Corps of Engineers to estimate the significant wave height and wave period using these parameters.

4.3.2 Wind Speed

Hourly wind speed and direction have been measured at Comox Airport since 1953. Figure 2 shows a wind rose summarizing the speed and frequency by direction. The dominant winds come from the southeast, South-southeast and northwest directions. Figure 3 shows a frequency plot of extreme winds from the southeast direction.

Table 3: Frequency of hourly wind speeds at Comox Airport

Return Period (Years)	Observed Speed (m/s)	Adjusted 10 m height (m/s)
2	20.3	17.8
5	21.6	18.9
10	22.5	19.7
20	23.5	20.5
50	24.8	21.7
100	25.7	22.5
200	26.7	23.4

4.3.3 Wave Height

Deep water wave heights were estimated using wave hindcasting methods developed by Kamphius. The waves were generated using the wind speed data in Table 3, assuming a fetch length of 90 km (south east storm conditions). Table 4 summarizes the estimates southeast deep water wave characteristics.

Table 4: Wave heights generated by southeast storms

Return Period (Years)	Hs (m)	Tp (sec)
2	2.8	7.4
5	3.0	7.6
10	3.1	7.7
20	3.2	7.8
50	3.4	7.9
100	3.5	8.0
200	3.7	8.1

For comparison, a moderately severe southeast storm occurred on October 29, 2014. This event was noted to cause wave attack at Goose Spit Park near Comox because the peak of the storm coincided with a relatively large high tide. Figure 4 summarizes the observed wind speed and wind direction at Ballenas Island and Sentry Shoal as well as the significant wave height at Sentry Shoal wave buoy during this event. The wind speed at Ballenas Island varied between 16 and 17 m/s during this storm. Setting the storm duration at 6 hours, the predicted deep water wave height was 2.2 m, which is close to the measured value of 2.3 m at Sentry Shoal wave buoy. This comparison demonstrates that the wave hindcasting estimates are reasonable.

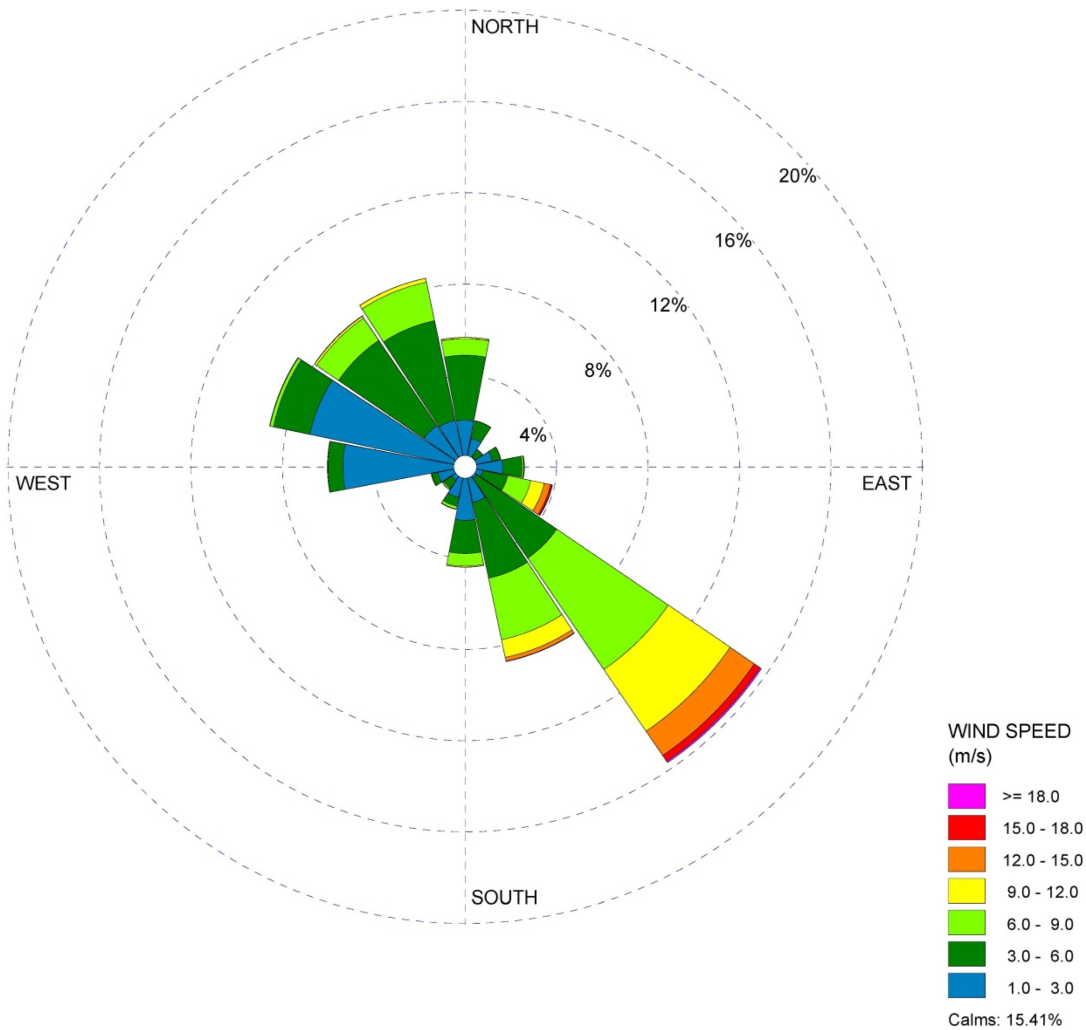

Figure 2: Wind rose at Comox Airport

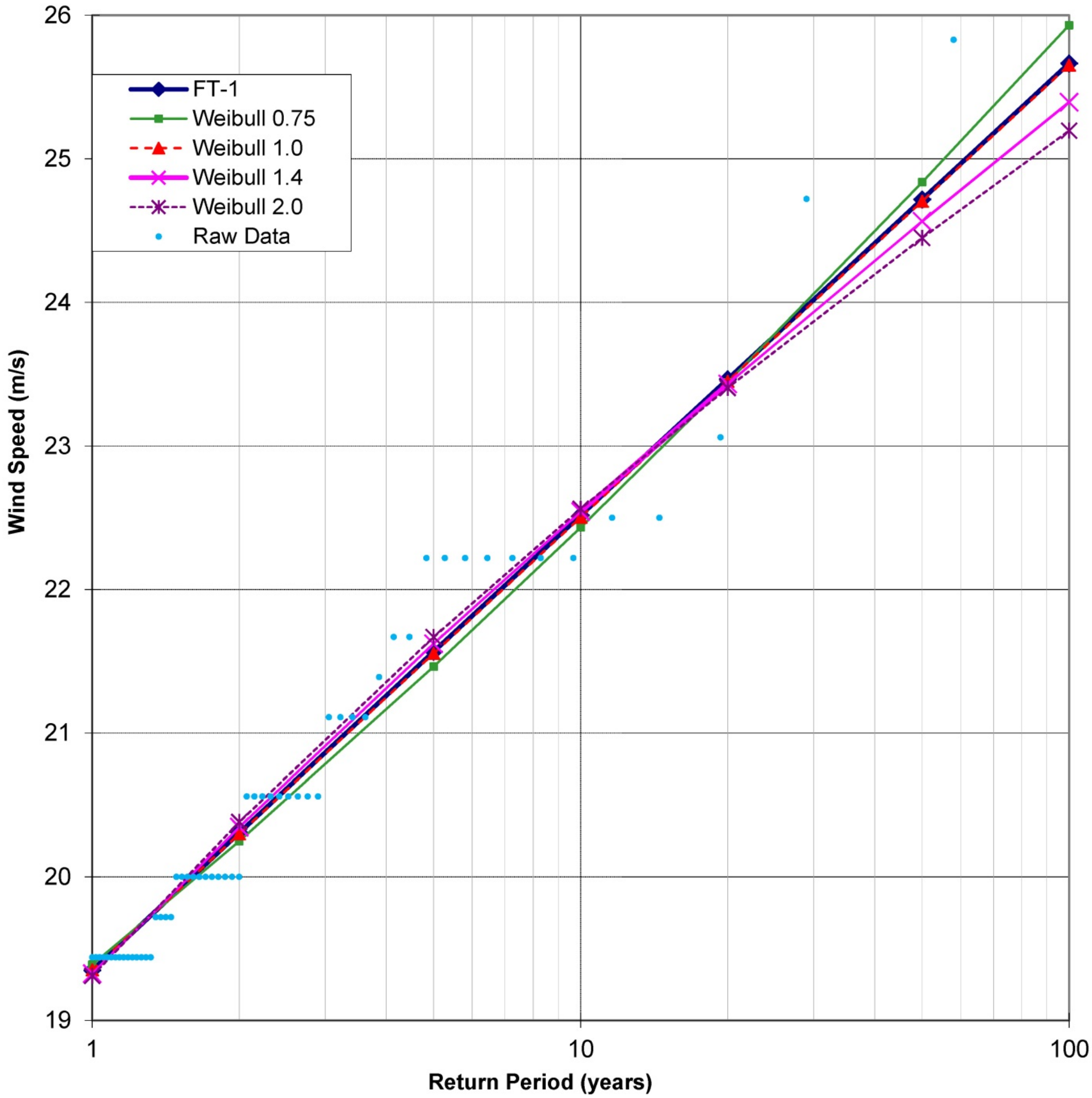

Figure 3: Wind speed frequency analysis, southeast winds at Comox Airport

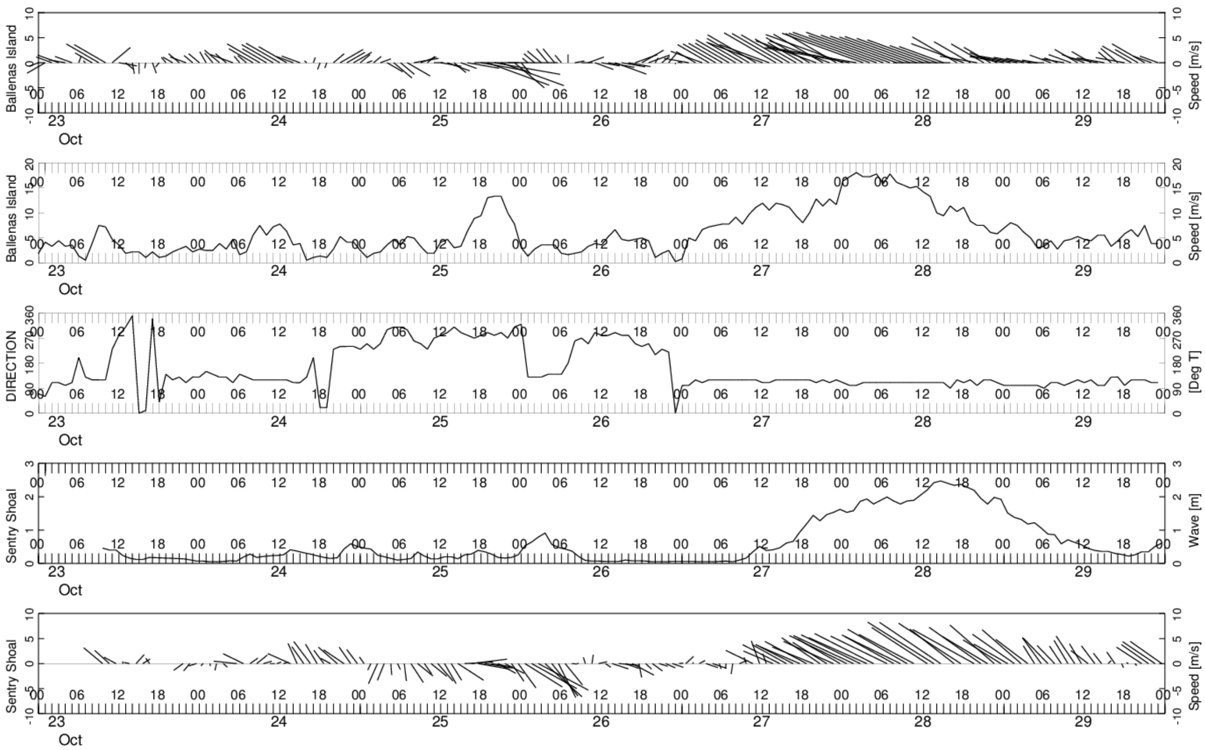

Figure 4: Met-ocean conditions, October 23 to 29, 2014 near Comox

4.4 Conditions in the Surf Zone

The deep water waves are subject to shoaling, refraction, attenuation and breaking as they approach the shoreline. Southeast waves approach virtually straight on to the shore at the site and will experience only minor refraction effects. The waves will steepen as they move into shallow water until they eventually break. The wave breaking characteristics are described in terms of the surf similarity parameter ξ

$$\xi = \frac{\tan(\beta)}{\sqrt{\frac{H_0}{L_0}}}$$

where β is the beach slope, H_0 is the wave height and L_0 is the wave length.

Low ξ values (<0.3) typically indicate dissipative conditions (high breaking waves on flatter beaches), while higher values (>1) indicate more reflective beaches (breaking waves on steep beaches). Based on the deep water wave characteristics and typical beach slopes near the site, the waves will break as spilling waves, where the crest becomes unstable and cascades down the shoreward face of the wave, producing a highly turbulent foaming water surface. The broken waves will continue shoreward as an irregular "bore", producing a swash zone, consisting of wave uprush and downrush. The maximum extent of the uprush is defined as the run-up level (Figure 5).

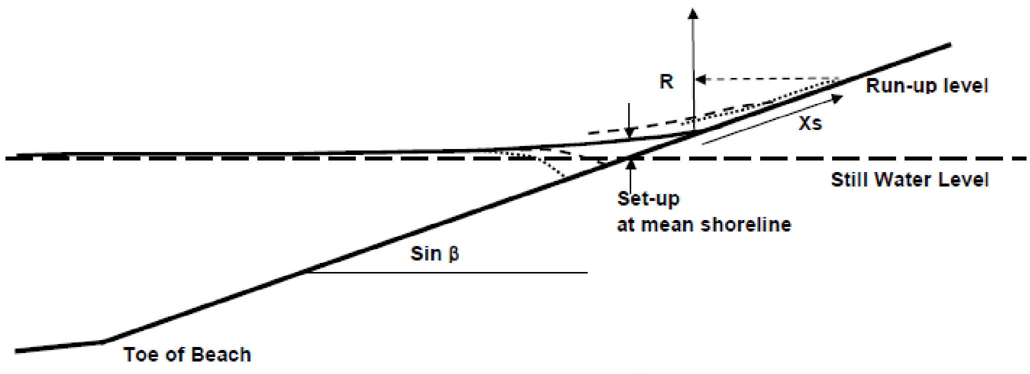

Figure 5: Wave set-up and run-up in the surf zone

The values of the breaker height(H_B),and depth at breaking (d_B), were estimated using methods developed by the US Army Corps of Engineers (EM 1110-2-1100), published in 2002. Van Rijn indicated that for ξo values < 0.3 the most reliable estimate of wave run-up on natural beaches can be determined by:

$$R_{2\%} = 0.043\sqrt{(H_0\,L_0)}$$

Estimates of wave breaking conditions and run-up for the 2 year, 10 year, 50 year and 200 year storms are summarized in Table 5.

Table 5: Wave breaking and wave run-up conditions.

Return Period (Years)	H_b (m)	d_B (m)	$R_{2\%}$(m)	WSEL (m CGD)	
				Present	2045
2	3.1	3.3	0.7	4.0	4.3
10	3.4	3.7	0.7	4.1	4.4
50	3.7	3.8	0.8	4.2	4.5
200	4.0	4.2	0.9	4.4	4.7

Where WSEL is the maximum water level reached by the wave run-up.

During a 200 year storm event, the waves will begin to break at a water depth of 4.2 m. For the adopted design SWL of 2.8 m CGD (2014 condition), this means the waves will start to break offshore at a beach elevation of -1.4 m CGD. This point is more than 50 m offshore from the upper foreshore. Therefore, the magnitude of the waves directly attacking the backshore and edge of the road is limited by the water depth along the shoreline. Table 6 summarizes depth-limited wave heights for a range of elevations on the foreshore, for both present (2014) and future (2045) sea level conditions. For example, the largest wave that can reach elevation +1.0 m CGD before breaking is 1.7 m (H_s).

Table 6: Depth-limited wave heights at varying beach elevations

Depth (m)	Beach Elevation (m CGD)		Wave Height (H_s m)
	Present Conditions	2045 Conditions	
1.3	+1.5	+1.8	1.2
1.8	+1.0	+1.3	1.7
2.3	+0.5	+0.8	1.9
2.8	0.0	+0.3	2.4
3.3	-0.3	0.0	2.9
4.2	-1.4	-1.1	4.0

Note: SWL = 2.8 m CGD (present), SWL = 3.1 m CGD (2045)

Landward of the break, the swash zone is exposed to broken waves and wave run-up. The estimated run-up elevation (2% exceedance) is given in Table 5. These results show that during a 2 year storm event, 2% of the broken waves will exceed elevation 4.0 m CGD. During a 200 year storm, 2% of the broken waves will exceed elevation 4.4 m CGD. The runup elevation (WSEL) is shown for both present conditions and future (2045) conditions to account for sea level rise.

5 EROSION PROTECTION

The analysis in Section 4 indicates that the intensity of wave attack at the site varies significantly with its elevation. Therefore, the type of erosion protection measures that are appropriate also depend on their location and elevation range. Bio-engineering solutions are most appropriate for higher elevation areas in the backshore that are subject to wave run-up, but not to direct wave attack. Conventional riprap revetments are necessary for protecting lower sections of the foreshore that are exposed to direct wave breaking. A combination of riprap and anchored LWD structures (a Green Shores approach) could be considered for intermediate levels between these zones.

Table 7 provides a preliminary classification of protection measures by elevation range for the site. Vegetation methods alone should be appropriate for areas lying above elevation 4.4 m CGD. Either riprap or anchored LWD (Green Shores designs) should be feasible for areas lying between elevations 3.2 and 4.4 m CGD. Riprap protection is appropriate for areas lying below elevation 3.2 m CGD.

Table 7: Wave attack by elevation (does not account for sea level rise)

Elevation Range (m CGD)	Wave Conditions	Type of Protection	Riprap Size	
			Mass (M_{50}kg)	Diameter (D_{50}mm)
+4.4	Spray, wave run-up (< 2% exceedance)	Vegetation, LWD	n/a	n/a
+3.2 to +4.4	Wave run-up	Anchored LWD /Riprap		
+2.1 to + 3.2	Wave run-up and depth limited waves	Riprap	600	700
+1.0 to +2.1	Wave run-up and depth limited waves	Riprap	2,100	1,050
0.0 to +1.0	Wave run-up and depth limited waves	Riprap	4,250	1,300

This table also provides preliminary estimates of riprap sizes (D_{50}) for each elevation band. The riprap sizes assumes a minimum two stone thick cover layer placed on a slope of 1V:2H or flatter. The stone sizes for depth-limited waves was determined using the Hudson formula. The stone sizes in the wave run-up zone was estimated using equations developed by Lorang (2000)[3].

6 CONCLUSIONS

Requirements for erosion control are governed by elevation at the site. Higher areas on the backshore (above elevation 4.4 m CGD) will be exposed to spray and only occasional wave run-up. Areas lying between elevation 4.4 and 3.2 m CGD will be exposed to wave run-up but not direct unbroken wave attack. Green Shores methods, incorporating anchored LWD and/or riprap would be appropriate. Areas below elevation 3.2 m CGD will be subject to depth-limited waves and wave run-up and will require riprap protection.

At present, the location and elevation of the proposed erosion protection measures have not been available to NHC for review. Once this information is provided, we will review the erosion protection components of the project and may need to refine or modify the wave parameters to match the actual design conditions. Therefore, the results contained in this letter report are provisional, pending the review of proposed design.

[3] Lorang, M. 2000: Predicting Threshold Entrainment Mass for a Boulder Beach, Journal of Coastal Research, Vol. 16, No. 2, pg. 432-445.

Sincerely,

Northwest Hydraulic Consultants Ltd.

original signed by

Dave McLean, Ph.D., P.Eng.
Principal

PHOTOGRAPHS

Photo 1: Viewing south, top of road el. = 3.8m, base of backshore el. 2.8m, WL = 1.0 m CGD (approximately).

Photo 2 (4079): Midden site, top of berm is at approximately elevation 3.5m CGD.

Photo 3 (4087): Top of berm el. = 5.4m; base of slope el. = 3.0m; ocean level = 1.3m CGD

Photo 4 (4086): Top of berm el. = 4.5m; top of riprap el. = 3.5m; ocean level = 1.3m CGD